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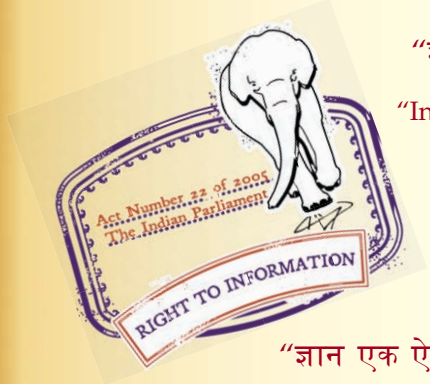

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IS : 3261 - 1980
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Indian Standard

SPECIFICATION FOR CARBON STEEL FORGINGS FOR SHIPBUILDING INDUSTRY

(First Revision)

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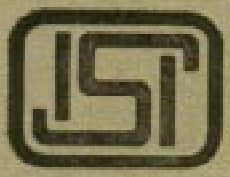

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1981

Indian Standard

SPECIFICATION FOR CARBON STEEL FORGINGS FOR SHIPBUILDING INDUSTRY

(First Revision)

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(*Continued on page* 16)

Indian Standard

SPECIFICATION FOR CARBON STEEL FORGINGS FOR SHIPBUILDING INDUSTRY

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 10 December 1980, after the draft finalized by the Steel Forgings Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was first published in 1966. On the basis of experience gained in the production and use of forgings it has been decided to revise the standard.

0.3 The following major modifications have been incorporated in this revision:

a) Steel designation has been included in accordance with IS : 1762 (Part I)-1974*.
b) Provision for check analysis has been made.
c) Several additional grades of carbon steel which are used for production of forgings for shipbuilding industry have been included.

0.4 This standard contains clauses **4.2**, **4.4** and **6.2.2** which permit the purchaser to use his option for selection to suit his requirements.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the requirements for 8 grades of carbon steel forgings required for shipbuilding purposes.

*Code for designation of steels: Part I Based on letter symbols (*first revision*).
†Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 1956* shall apply.

3. SUPPLY OF MATERIAL

3.1 General requirements relating to the supply of carbon steel forgings shall conform to IS : 1387-1967†.

4. MANUFACTURE

4.1 Forgings shall be manufactured from killed steel produced by the open hearth, electric or any other process approved by the inspecting authority.

4.2 Forgings shall be brought as nearly as possible to the finished shape and size by hot working and shall, where practicable, be so worked as to cause grain flow in the most favourable direction for resisting the service stresses, which should be made known to the supplier by the purchaser.

4.3 Except as specified in **4.3.1** to **4.3.3**, and unless otherwise approved by the inspecting authority, the maximum cross-sectional area of any part of the forgings (as forged) shall not exceed:

a) 1/3 *A* where the length of any section is greater than its diameter, and

b) 2/3 *A* where the length of any section is less than its diameter.

where *A* is average sectional area of the ingot or of the ingot after upsetting, if such an operation is involved.

4.3.1 Turbine discs and other ring type or disc type forgings shall be made from cylindrical pieces which have been cut or machined from a bloom or billet. The thickness of any part of a disc (as forged or as stamped) shall not be more than one-half of the length of the piece from which it was formed.

4.3.2 For rotor forgings of turbines, compressors and turbine driven generators, the maximum cross-sectional area of any part of the forging

*Glossary of terms relating to iron and steel :
(Part I)-1976 General metallurgy, heat treatment and testing.
(Part II)-1976 Steel making
(Part III)-1975 Hot rolled steel products (excluding sheet and strip)
(Part VI)-1976 Forging (including drop forging)

†General requirements for the supply of metallurgical materials (*first revision*).

(as forged) shall not exceed one-half of the average cross-sectional area of the ingot or upset bloom.

4.3.3 For spindle forgings of the turbines, compressors, and turbine driven generators, the cross-sectional area of any part (as forged) shall not exceed one-third of the average cross-sectional area of the ingot except at collars where the area is not to exceed two-thirds of the cross-sectional area of the ingot.

4.4 The forgings shall be free from all defects and shall be finished to the prescribed dimensions within limits as agreed to between the purchaser and the supplier. Defects in forgings shall not be repaired without the previous sanction of the inspecting authority.

4.5 The shaping of forgings or thick slabs by flame cutting shall be undertaken in accordance with the procedure approved by the inspecting authority. For machinery parts that are subjected to cyclic stresses during service, a depth of at least 12·5 mm shall be removed by machining from flame cut surfaces.

5. CHEMICAL COMPOSITION

5.1 The composition of the carbon steel for large forgings having a ruling section greater than 150 mm as well as for small forgings intended for stressed applications when analysed in accordance with relevant parts of IS : 228* shall be as given in Table 1.

5.1.1 *Check Analysis* — The check analysis shall be conducted on finished forging. The permissible deviation in case of check analysis from the limits specified in Table 1 shall be as follows:

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*Methods of chemical analysis of steels:

Part I Determination of carbon by volumetric method (for carbon ≥ 0·1 percent (*second revision*)

Part II Determination of manganese in plain carbon and low alloy steels (Arsenitic method) (*second revision*)

Part III Determination of phosphorus (Alkalimetric method) (*second revision*)

Part IV Determination of carbon (gravimetric method) for carbon ≥ 0·1 percent (*second revision*)

Part VIII Determination of silicon by gravimetric method (for silicon ≥ 0·1 percent) (*second revision*)

Part IX Determination of sulphur in plain carbon steels by evolution method (*second revision*)

Constituent, Percent	*Permissible Variation, Percent, Max*	
	For sections 250 mm² or less	For sections 250 mm² to 500 mm²
Carbon:		
Up to 0·25	±0·02	±0·04
Over 0·25 up to and including 0·50	±0·03	±0·05
Over 0·50	±0·04	±0·06
Silicon	±0·03	±0·04
Manganese	±0·04	±0·07
Sulphur	±0·005	±0·010
Phosphorus	±0·005	±0·010

NOTE — Variations shall not be applicable both over and under the specified limits in several determinations in a heat.

5.2 Elements not specified in Table 1 shall not be added to the steel, except when agreed to, other than for the purpose of finishing the heat and shall not exceed the following limits:

Constituent	*Percent*
Nickel	0·25
Chromium	0·25
Copper	0·35
Molybdenum	0·05
Vanadium	0·05
Tin	0·05

6. HEAT TREATMENT

6.1 At an appropriate stage of manufacture, after completion of hot working operations, each forging shall be suitably heat-treated in a furnace which shall permit the whole forging to be uniformly heated throughout to the necessary temperature. If for any reason a forging is subsequently heated for further hot working, the forging shall be re-heat-treated.

6.2 Heat treatment by one of the following methods shall be applied to obtain the desired mechanical properties.

6.2.1 The forgings shall be heated to a uniform temperature above the upper critical point to refine the grain and shall then be:

a) fully annealed by cooling slowly in the furnace in a uniform manner, or

b) normalized by cooling in still air, or

c) hardened by quenching in oil or by other recognized method, followed by tempering.

TABLE 1 CHEMICAL COMPOSITION

(*Clause* 5.1)

Class	Designation [*see* IS : 1762 (Part I)-1974*]	Constituent, Percent				
		Carbon	Silicon	Manganese	Sulphur, *Max*	Phosphorus, *Max*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1A	15C8	0·10 to 0·20	0·15 to 0·35	0·60 to 0·90	0·050	0·050
2	20C8	0·15 to 0·25	0·15 to 0·35	0·60 to 0·90	0·050	0·050
2A	25C8	0·20 to 0·30	0·15 to 0·35	0·60 to 0·90	0·050	0·050
3	30C8	0·25 to 0·35	0·15 to 0·35	0·60 to 0·90	0·050	0·050
3A	35C8	0·30 to 0·40	0·15 to 0·35	0·60 to 0·90	0·050	0·050
4	45C8	0·40 to 0·50	0·15 to 0·35	0·60 to 0·90	0·050	0·050
5	55C8	0·50 to 0·60	0·15 to 0·35	0·60 to 0·90	0·050	0·050
6	65C6	0·60 to 0·70	0·15 to 0·35	0·60 to 0·90	0·050	0·050

Note 1 — For welded construction for ship or machinery, carbon content of the steel shall not exceed 0·22 percent.

Note 2 — For turbine rotors, discs and spindles, turbine driven generators, rotors and compressor rotors carbon content shall not exceed 0·45 percent.

Note 3 — Where mechanical tests are required from forgings in either the radial or the tangential direction or both, the sulphur and the phosphorus contents of the steel shall not be more than 0·040 percent each.

Note 4 — For gear wheels the sulphur or phosphorus content shall not exceed 0·040 percent.

Note 5 — When the steel is aluminium-killed or killed with both aluminium and silicon, the requirements of silicon content shall not apply.

Note 6 — When the steel is made by oxygen process, the nitrogen content shall not exceed 0·009 percent.

*Code for designation of steels: Part I Based on letter symbols.

6.2.1.1 If having regard to the carbon content, the ruling section of the forging is equal to or greater than the equivalent diameter given below, the normalizing treatment shall be followed by a tampering (stress-relieving) treatment.

Carbon, Percent		*Equivalent Diameter*
Over	Up to and including	mm
0·40	0·50	400
0·35	0·40	500
0·30	0·35	700
0·25	0·30	900
—	0·25	1 000

Other forgings may be tempered (stress relieved) after normalizing at the option of the forgemaster.

6.2.2 Treatment given in **6.2.1** (c) shall not be adopted without prior agreement between the supplier and the purchaser.

7. NUMBER OF TESTS

7.1 For the purpose of mechanical tests, sufficient material of not less than the sectional dimensions of the body shall be formed integral with forging. This material shall not be removed from the forging until the heat treatment is completed and the forging as well as the test material stamped for identification by the inspection authority, except where an alternative procedure has been specially approved.

7.2 For general carbon steel forgings of large cross-section at least one tensile and one cold bend test piece shall be taken from each forging (or multiple forging). In case of forgings or multiple forgings exceeding both 3 000 kg in weight and 2·44 m in length, one tensile and one cold bend test piece shall be taken from each end of each forging or multiple forging.

7.3 For small forgings where quantity production is involved, batch testing may be adopted. In such cases, forgings shall be presented for test and inspection in groups of the same cast and the same heat treatment batch.

7.4 For forgings of turbine rotors and spindles, turbine driven generators, rotors and compressor rotors, at least one longitudinal tensile and one cold bend test piece shall be taken to represent the material of each forging (or multiple forgings) exceeding both 3 000 kg in weight

and 1·83 m in length not less than one tensile and one cold bend test piece shall be taken from each forging (or multiple forging).

7.4.1 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1 500 SHP tangential and where dimensions permit, radial tensile and bend test pieces shall also be taken from the end of the body corresponding to the top end of the ingot.

7.4.2 For each turbine disc, at least one tensile and one bend test piece shall be cut in a tangential direction from material at the hub.

7.5 For single gear wheel or wheel-rim forgings greater than 2·44 m in diameter or 3 000 kg in weight and for multiple forgings, one set of circumferential test pieces consisting of one tensile and one bend test piece shall be taken from each end of the forging from the positions diametrically opposite, provided that in the case of multiple forgings all the portions cut from it are heat treated together. For smaller single wheels or rims, a set of circumferential test pieces shall be taken from one end of the forging.

8. MECHANICAL TESTS FOR GENERAL CARBON STEEL FORGINGS

8.1 Tensile Test

8.1.1 Tensile test shall be carried out on standard test pieces prepared in accordance with IS : 1608-1972*.

8.1.2 The tensile strength and percentage elongation of the forgings shall be as given in Table 2.

8.1.2.1 Yield stress shall be determined when so specified by the purchaser for certain machinery forgings. For crank webs, the minimum yield stress shall be 210 N/mm^2.

8.2 Bend Test

8.2.1 Bend test pieces shall be machined to a rectangular section of either 25 mm wide × 20 mm thick, where the specified minimum tensile strength of the steel does not exceed 560 N/mm^2 or 20 mm wide × 10 mm thick, where the specified minimum tensile strength exceeds 560 N/mm^2. The edges of the test pieces may be rounded to a radius of not more than 1·5 mm in each case.

8.2.2 Bend test shall be conducted in accordance with IS : 1599-1974†.

*Method for tensile testing of steel products (*first revision*).
†Method for bend test for steel products other than sheet, strip, wire and tube.

TABLE 2 TENSILE TEST

(*Clause* 8.1.2)

Actual Tensile Strength N/mm²	Elongation on 5·65 $\sqrt{So}$ Percent, Minimum	
	Longitudinal or in the Direction of Principal Grain Flow	Transverse or Across the Direction of Principal Grain Flow
Over 340 up to 390	27	22
,, 390 ,, 440	25	21
,, 440 ,, 490	23	19
,, 490 ,, 540	22	18
,, 540 ,, 590	20	16
,, 590 ,, 640	18	14
,, 640 ,, 690	16	12

NOTE 1 — Specified range of tensile strength for any forging shall not exceed 79 N/mm².

NOTE 2 — Where tensile test pieces are taken from each end of a forging or multiple forging, the test results shall not vary by more than 63 N/mm².

8.2.3 Bend test pieces shall withstand, without fracture, being bent cold through 180° round a former having diameter not greater than that specified in Table 3 according to the tensile strength. The test pieces shall be bent over the thinner section.

TABLE 3 INTERNAL DIAMETER OF BEND

Tensile Strength N/mm²	Maximum Internal Diameter of Bend	
	Longitudinal or in the Direction of Principal Grain Flow	Transverse or Across the Direction of Principal Grain Flow
Up to 490	2/3 t	1⅓ t
Over 490 up to 590	t	2 t
Over 590 ,, 690	2 t	4 t
Over 690	3 t	5 t

t = thickness of test piece.

8.2.4 Where a number of individual forgings of the same type are produced, a system of batch testing may be adopted by the inspecting authority. In such cases, forgings are to be presented for test and inspection in groups of the same cast and the same heat treatment batch.

8.2.4.1 Where a system of batch testing is adopted, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile and bend test pieces. The hardnesses of the forgings shall comply with a specification approved by the inspecting authority before manufacture of the parts.

9. MECHANICAL TESTS FOR CARBON STEEL FORGINGS FOR TURBINE ROTORS, DISCS AND SPINDLES, TURBINE DRIVEN GENERATORS, ROTORS AND COMPRESSOR ROTORS

9.1 Tensile Test

9.1.1 Tensile test shall be carried out on standard test pieces prepared in accordance with IS : 1608-1972*. For longitudinal and transverse test pieces, the cross-sectional area shall not be less than 1·6 cm² and for radial test pieces not less than 0·65 cm².

9.1.2 The percentage elongation, when determined in accordance with IS : 1608-1972*, shall be as given in Table 4.

TABLE 4 PERCENTAGE ELONGATION, *Min*

Specified Minimum Tensile Strength	Minimum Percentage Elongation for Gauge Length of $5{\cdot}65\sqrt{So}$			Maximum Diameter of Former for Bend Test		
				180°	150°	120°
N/mm²	L	T	R	L	T	R
440	24	20	17	2t	2t	2t
490	23	19	16	2t	2t	2t
540	22	17	15	2 2/3t	2 2/3t	2 2/3t
590	19	16	14	4t	4t	4t
690	17	14	12	4t	4t	4t
780	16	12	10	4t	4t	—
880	15	11	—	6t	6t	—
980	14	10	—	6t	6t	—

9.1.2.1 Unless otherwise specified and approved, the yield stress or 0·5 percent proof stress of steel, shall not be less than 50 percent of the actual tensile strength for normalized material.

9.1.2.2 The reduction of area at fracture as determined on tensile test pieces shall not be less than:

a) 35 percent for longitudinal test,

b) 30 percent for transverse test, and

c) 20 percent for radial test.

*Method for tensile testing of steel products (*first revision*).

9.2 Bend Test

9.2.1 Bend test pieces shall be machined to a section of 20 mm by 10 mm. The edges of the test pieces may be rounded to a radius of not more than 1·5 mm. Bend test shall be conducted in accordance with IS : 1599-1974*.

9.2.2 The test pieces shall be bent cold without fracture through 180° for a longitudinal test piece; 150° for tangential test piece; and 120° for a radial test piece. The maximum diameter of the former over which the bend test shall be conducted is given in Table 5.

TABLE 5 MAXIMUM DIAMETER OF FORMER FOR BEND TEST

Specified Tensile Strength, *Min* N/mm²	Diameter of Former, Maximum		
	Longitudinal	Tangential	Radial
	180°	150°	120°
(1)	(2)	(3)	(4)
430	20	20	20
450	20	20	20
530	25	25	25
620	40	40	40
700	40	40	40

10. MECHANICAL TESTS FOR CARBON-STEEL FORGINGS FOR GEAR WHEELS

10.1 Tensile Tests

10.1.1 Tensile test shall be carried out on standard test pieces, prepared in accordance with IS : 1608-1972*.

10.1.2 The yield stress and percentage elongation after fracture of tensile test pieces shall be as given in Table 6.

10.1.3 Unless otherwise specified and approved, the yield stress of steel shall not be less than that given in Table 6.

10.2 Bend Test

10.2.1 Bend test pieces shall be machined to a rectangular section of 25 mm wide ×20 mm thick for steel not exceeding 620 N/mm² tensile strength and 20 mm wide ×10 mm thick where the tensile strength exceeds 620 N/mm². The edges may be rounded to a radius of 1·5 mm in each case.

*Method for bend test for steel products other than sheet, strip, wire and tube (*first revision*).

†Method for tensile testing of steel products (*first revision*).

10.2.2 Bend test shall be conducted in accordance with IS : 1599-1974*.

10.2.3 The test pieces shall withstand without fracture, being bent cold through 180° over a former having a diameter not greater than that specified in Table 6. They shall be bent over the thinner section.

TABLE 6 MECHANICAL PROPERTIES FOR CARBON STEEL FORGINGS FOR GEAR WHEELS

(*Clauses* 10.1.2, 10.1.3 *and* 10.2.3)

STEEL	HEAT TREATMENT	MINIMUM YIELD STRESS N/mm²	SPECIFIED MINIMUM TENSILE STRENGTH N/mm²	MINIMUM ELONGATION PERCENTAGE $5{\cdot}65\sqrt{S_o}$		BEND TEST MAXIMUM DIAMETER OF FORMER	
				Long	Trans (*See* Note)	Long	Trans (*See* Note)
Carbon or carbon manganese	Normalised and tempered or oil hardened and tempered.	225	440	23	19	$2/3t$	$1\frac{1}{3}t$
		245	490	22	18	$2/3t$	$1\frac{1}{3}t$
		275	540	20	16	t	$2t$
		295	590	18	14	t	$2t$
		325	640	17	12	$2t$	$4t$
		345	690	16	11	$2t$	$4t$

NOTE — Circumferential test pieces from rim forgings are to give longitudinal properties.

10.3 Hardness Test — Except in special cases where prior approval is taken from the inspecting authority, hardness test shall be made on all forgings after machining to 6·5 mm over the finished diameter after heat treatment. The impressions shall be taken at each end of two diameters at right angles in three different positions over each toothed portion of the opinion. The forging shall be considered sufficiently uniform if the difference between the highest and lowest value does not exceed 20 in Brinell numbers or their equivalent for steels of tensile strength not exceeding 620 N/mm² and 30 in Brinell number for steels over 620 N/mm².

11. RETESTS

11.1 Should either a tensile or bend test fail to pass the tests specified in the standard, two further tests shall be made from the same forging in respect of each failure. Should the results of both these additional tests are satisfactory, the forgings shall be accepted provided that in other respects they fulfil the conditions of the specification. If any of these additional tests does not give satisfactory results the forgings represented

*Method for bend test for steel products other than sheet, strip, wire and tube (*first revision*).

may be re-heat-treated and presented to the inspecting authority for further testing. If any test, made after the permissible number of heat treatments, fails to meet the requirements of the standard, the forging shall be liable to rejection. No forging shall be re-heat-treated more than twice.

12. INSPECTION AND MARKING

12.1 General Carbon Steel Forgings

12.1.2 The inspecting authority shall examine each forging. In the case of forgings for crankshafts which have finished pin or journal in excess of 510 mm diameter, the supplier shall carry out an ultrasonic test in the presence of the inspecting authority. In the event of any forging proving unsound during subsequent machining, erection of trials, such forging shall be rejected notwithstanding any previous certificate of satisfactory test and inspection.

12.1.2 Every forging, after it has withstood satisfactorily the prescribed tests and inspection, shall be clearly marked by the inspecting authority indicating that the forging has complied with the requirements of the standard.

12.1.2.1 When forgings are ordered in fully machined condition, the identification marks shall be transferred by the inspecting authority after full machining.

12.2 Turbine Rotors, Discs and Spindles, Turbine Driven Generator Rotors and Compressor Rotors

12.2.1 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1 500 SHP shall be hollow bored for internal examination. The surfaces of the bores shall have a fine, smooth-finish. Suitable optical instrument shall be provided for examining the bores. Alternative methods for detection of internal soundness of the forgings may be accepted, if thought fit by the inspector.

12.2.2 The end faces of rotor forgings shall be machined to a fine smooth finish for the purpose of examination.

12.2.3 The end faces of the boss and the bore surface of each turbine disc shall be machined to a smooth finish and examined by a magnetic crack detection method.

12.2.4 All solid forged HP steam and gas turbine rotors intended for main propulsion service where the inlet steam or gas temperature exceed 400°C shall be subjected to at least one thermal stability test. The stability test shall also be carried out for forgings of rotors joined by welding.

12.2.5 The details of the test to be carried out shall be furnished by the inspecting authority and the particular mention shall be made in the specification for carrying out such tests by the purchaser.

12.2.6 In the case of rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor shall be submitted to inspecting authority for special consideration.

12.2.7 Every forging, after it has withstood satisfactorily the prescribed tests and inspection, shall be clearly marked by the inspecting authority indicating that the forging has complied with the requirements of this standard. When forgings are ordered in fully machined condition, the identification marks shall be transferred by the inspector after full machining.

12.3 Gear Wheel Forgings

12.3.1 The inspecting authority shall examine each forging. For such examination, sulphur prints shall be taken from the ends of the wheel rim to varify that the steel is clean and free from harmful segregation. Other optional test like magnetic crack detection may be conducted subject to mutual agreement between the inspector and the supplier.

12.3.2 The teeth of all surface and case hardened wheel shall be examined for cracks and other imperfections by magnetic crack-detection method.

12.2.3 Every forgings, after it has withstood satisfactorily the prescribed tests and inspection, shall be clearly marked by the inspecting authority indicating that the forging has complied with the requirements of this standard. When forgings are ordered in fully machined condition, the identification marks shall be transferred by the inspecting authority after full machining.

12.4 The forgings may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

(*Continued from page* 2)

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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